SUGGESTIONS FOR THE DEVELOPMENT OF THE ARTS AND SCIENCES.

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It is often said that we are rapidly approaching a limit to the development of the Arts and Sciences; that the next century will not witness as much progress in this direction as the present. We have discovered the correlation of forces, and the conservation of energy, found the mechanical equivalent of heat, formulated an electro-magnetic theory of light, and made wonderful applications of steam and electricity. We have found the missing link in the chain of evolution. There are strong reasons, however, to believe that the Arts and Sciences will make far greater progress in the immediate future than ever in the past.

The words Arts and Sciences are used in the most general sense. Both relate to investigations of truth, but Science inquires for the sake of knowledge, Art for the sake of production. A Science teaches us to know, an Art to do. In Art truth is a means to an end, in Science it is the only end.

No Arts are possible unless they are founded on Sciences, and Sciences depend on generalizations. By induction individuals are raised to generals, and these to higher generalities. By deduction universals are brought down to lower genera and to individuals. A knowledge of facts is mainly useful as a basis for Science. Whatever may be the aim of Philosophy or Religion, the final object of the Arts and Sciences should be to ascertain laws to apply to acts.

The tendency of the age has been to specialize. As a reaction against the mediæval practice of framing theories on insufficient foundations, most of the scientific work of modern times has been devoted to collecting facts, arranging and classifying them; and those who have devoted their lives to investigating abstract laws and principles have been out of touch with those who have handled the facts to which the laws apply. All the professions have been driven into independent channels. A university town has been likened by its inhabitants to an archipelago.

It has been said that the chemist and the physicist should be diametrically opposite in their ways of thinking and working. If so it is very important that the results of each should be put in proper shape to be utilized by the other. The chemist requires aid from the physicist, the physicist from the mathematician, the engineer from all. The historian requires aid from the linguist, and the economist from the historian. Every art and science, and every calling in life, is dependent for its proper development on every other, and should be able to apply the results that have been worked out by specialists in all branches.

Systematic co-operation is still more requisite between those of the same profession than between those of different professions; it is in fact another name for civilization. Without co-operation we should soon be reduced to the condition of paleolithic man, and forced to hunt reindeer with clubs, or if we should congregate it would only be to sit on shell mounds and eat oysters.

It is time to build up Science on broad foundations. We cannot all be specialists hereafter. The results of our labor must be put together in such shape as to be utilized. And to this end new means of communication must be employed.

In every branch of science a complicated system of technical terms and hieroglyphics has been employed as a screen to keep off intruders and to hide the precious jewels from the profane glance of those who have not dug them.

Many of the papers read before our own society are intelligible only to the speakers. The listeners only recognize the language by occasional articles or prepositions.

In our efforts to scale the heavens and find out its secrets, we have been paralyzed by a confusion of tongues like our ancestors in the valley of the Euphrates four thousand years ago.

Technical terms and symbols are necessary and proper tools for the specialist to work with, but they are not the fruits of his labor to turn over to the world.

The technical language that acts as a barrier between different sciences is far from being all-sufficient for its own science. The specialist is forced to spend a valuable part of his life in assimilating the work of others before he can hope to advance the bounds of science even in the narrow field in which he is working. This involves a great dissipation of energy. Moreover, many sciences are so buried in their own symbols that the specialists are mystified about the purport of their discoveries. They take abstract formulæ to be the end, and not the means, of their work.

Hence the fear is not ungrounded that, under the present system, we cannot look for as much progress in the future as in the past.

In the reaction against wild speculation we should not go so far as to lose sight of the object of our work. Our predecessors built towers on such narrow foundations that they blew over. We have seen their trouble and have dug the foundations for a more stable edifice; and since the confusion of tongues, we have still been working along, cutting stone, dressing and polishing it, laying a few courses, and putting up scaffolding. But most of the stone is still in the quarries; it has yet to be handled; the building is to be erected; but the roads are bad; railroads and derricks are required, for we have now only hammers and chisels, and the quarries are so congested with stone that it must soon be removed.

To make co-operation effective, means must be devised by which the raw material may be handled, not only by the specialists, who have accumulated it, but also by all others working in allied sciences.

I do not refer to attempts to popularize science by presenting the shadow rather than the substance. All results, everything that is known, must be presented in such form as to be intelligible with the least expenditure of mental effort.

Neither do I refer to the instruction of youth, although I think that some of the methods required to build up science could also be applied to education.

The science and art of co-operative thought have yet to be created. System and tools must be invented both for the science and for the art. The nineteenth century has produced machinery for manufacture. The twentieth century will produce machinery for thinking. We can now only surmise what these methods and tools will be, but it is time to consider, and it is the duty of all interested in the Arts and Sciences to suggest.

The methods now employed for handling facts and principles are: —

First, making the human brain a kind of receptacle and pumping into it a little information during a short period of tutelage.

Secondly, consulting Encyclopædias and Libraries.

Thirdly, consulting professional experts.

These methods are insufficient. If the engineer has to make some new application of the principles of physics, is it convenient for him to read through volume after volume written in foreign and occult languages, tempered with mathematical hieroglyphics that conceal rather than express the author's meaning? Or must he renew the experiments

that have been made all over the world, invent his own apparatus, and draw his own inferences? Or shall he go to some learned physicist and ask him to explain all he knows about his science? Occasionally this would be very pleasant for both parties, — if the engineer did not want to know too much or too often, or if he paid enough for the advice.

These methods all have their advantages, but they will require modification or perfection hereafter. A great deal that is now hidden in symbols can be expressed in plain intelligible language, but language can no longer be the only means of communicating thought. Graphic methods are already employed on a small scale to represent mechanical and physical principles; so are synoptical tables, charts, etc. But these methods and their applications should be much extended, and in connection with them the very hieroglyphics employed by the specialists can be turned to good account.

We must use our eyes as well as our ears. Speech is addressed to the ear which receives but one impression at a time. We must avail ourselves of two dimensions of space instead of one. Suppose the problem were to find a needle in a dark room. We could find it much quicker by lighting a lamp than by feeling about in the dark until we had brought our fingers in contact with every part of the surface. We do indeed use our eyes in reading, but we read only words, words, words, that are addressed to the ear through the eye and convey only a single train of thought. We use our eyes like a blind man, and we follow King Lear's advice to Gloucester: "Look with thine ears . . . and, like a scurvy politician, seem to see the things thou dost not."

There is always more or less opposition to new methods. It is claimed by some that the labor spent in acquiring knowledge is necessary to improve the mind. One of the advocates of this doctrine commanded a flat-boat on the Mississippi River and combined this function with that of a preacher of the Gospel. He declined to tell his congregation where the text was to be found, because, he said, if they would search the Scriptures as he had searched them, they would find there not only his text, "but many other texts as would do 'em much good to read 'em."

Everything must be put in synoptic or cartographic form if possible. If we do not make such charts on paper, we must make them in our brain. By the present system the mind is overtaxed with the effort. If the charts are first made on paper, they are quickly photographed on the mind, and then the old methods can be applied in connection with them. If you have a map of the country, the guide-book will help to make it

more intelligible and interesting. Meander through the country by all means, but look at it from a balloon with a field glass on every available opportunity. Keep your map with you, and years hence you will recall what you have seen.

Scientific books should be supplied with classified tables of contents, so complete as to recall every idea worth remembering. The books might be so written as to be intelligible when opened in the middle. Where algebraic or other signs are used, they should also be thoroughly indexed. Models, of course, are far better than pictures. It is better to make use of three dimensions whenever possible rather than two, and movable models would give us four dimensions to work with. Neither charts nor models fatigue the mind any more than sentences, but in the same time they teach more and make more lasting impressions.

The systematic reduction of knowledge opens the way to systematic co-operation. The centrifugal tendencies of the age have been useful in scattering explorers over a wide field, but the waste of labor has been incalculable,— one after another has trodden the same path, when each should have begun his work where the other had ended. If facts and laws and principles are properly tabulated as soon as they are discovered, it will not be necessary for each man to set up an independent hypothesis, but the work of investigation can be properly distributed.

The methods employed in military operations for deploying scouts to explore the field of operations could be used to good advantage in all the sciences.

Napoleon and his staff were on the banks of the Red Sea at low water at the spot where the children of Israel were said to have crossed. After sunset they lost their path, and as they were wandering among the sands the rapidly returning tide surrounded them, and they would have met with the fate of Pharaoh, but Napoleon collected his escort around him in several concentric circles, each horseman facing outward. He then ordered them to advance, each in the direction he was facing. When the horse of the leader of one of these files lost his foothold and began to swim, the file drew back and followed in the direction of another file which had not yet lost its firm ground. The files thrown out in every direction were in this way successively withdrawn, till all were following in the direction of the one which had a stable footing. Thus the escape was effected, and by a similar method of co-operation the process of induction could be facilitated in all sciences.

In applying these principles to the separate sciences, Mathematics, Physics, and Engineering may be considered together.

Mathematics is usually spoken of as a deductive science, but it is also inductive. Klein divides the mathematicians into three classes, the logicians, formulists, and intuitionists. The intuitionists lay particular stress on geometrical intuition, — not in pure geometry only, but in all branches of mathematics. "What Benjamin Peirce calls geometrizing a mathematical question," says Klein, "seems to express the same idea." Each class is useful in its own sphere, but hereafter the sphere of the intuitionist will be vastly extended.

In mathematics and physics all analytical work can be put into geometrical shape, and so expressed that one or two pages will not only indicate but explain the work of a volume and help to recall its contents. In Analytic Geometry, as ordinarily treated, the Geometry is the object, the Algebra the means. In cartographic representation the Geometry not only explains itself, but explains the Algebra also.

Algebraical Formulæ should also be tabulated by themselves for some purposes. Tables of Integrals should be made as complete and systematic as possible, and form the basis for a treatment of the Integral Calculus.

The higher branches of mathematics lend themselves as readily to cartographic representation as the simpler branches.

The purely analytical methods of much of the mathematics of the nineteenth century make it comprehensible only to a mathematician, and only to him when he begins at the first chapter.

I had occasion once to look into a question of mathematical physics that was not so elementary as to be found in an engineer's pocket-book; and so I consulted a treatise on the special branch in which I was working. From the index and table of contents, I had no trouble in finding the place, but did not know what the letters stood for. I read the chapter through without learning, and then read the chapter before it. There were the same signs, and I was referred back to chapter after chapter, then to another book on general physics, which I read half through, and then to a book on mathematics, with no better result. Then I took up one of the books on physics again, and began at the Preface. I found nothing about the signs, but much about the Cambridge Tripos. I had not been connected with any university for several years, and I thought a Tripos was a thing to set a theodolite on. I looked in the dictionary, and found that it was a writer of Latin verses on the back of a slip of paper containing the names of bachelors who were highest in the list. That explained everything. The Latin verses were the end and motive of the whole system. The books were not meant to be understood

by anybody who did not go through the whole mill. In the innocence of my heart I wanted to find out something about fog-signals to save the lives of seamen, and I had been referred to the little Latin verses for boys. I then worked out the problem of general principles in less than a tenth of the time I had spent in looking it up.

Mathematics is regarded as an occult science, whereas in reality, if you only know what the letters mean, it is the plainest common sense. One of the leading scientists of America told me that he did not think the higher branches of mathematics were of any practical use; and one of the most noted inventors of the day even said, "Mathematics ain't no good." Before mathematicians can take the stand in the world to which their work entitles them, they must express their results in better shape.

In the science of Physics much would be gained by more perfect co-operation. The time has not yet arrived when all the laboratories in the world or in the country can so combine their labor that no work shall be uselessly duplicated, but doubtless there is more co-operation in a quiet way than is generally known.

In Physics and Engineering, graphic methods have long been employed. In 1892 the committee appointed by the British Association to look into this subject made its second report. This Association, and others of its type, have inaugurated a system of co-operation in science, but nothing to compare with what will soon be required. The report says: "It does not require much acquaintance with the subject to realize that there is scarcely a treatise or publication dealing with mechanical science that does not employ some kind of graphical expression as a means of exposition or calculation." These reports give a good index to the work up to that date.

Graphic methods afford the best means of mapping laws, and complete maps of all that are known would not only help to recall them, but would also aid in the solution of problems.

The immediate future will probably see a greater advance in the science of Physics than all past ages together. The correlation of forces and conservation of energy have already been established, but we know little as yet of the nature of the correlation except between light and electricity. We have not yet determined the nature of the ether, or that of atoms. Ethers have been hypothecated that answer for special purposes. The problem is to get one to do all the work required, and until that is found physicists and chemists should formulate and tabulate as simply as possible the conditions it must fulfil to account for phenomena. The solution of the problem will not be far away.

Trautwine's Pocket-Book for Engineers was first written as a protest against mathematics. It was a great help for a certain class of engineers, for it gave them the results of the work of mathematicians which they could not comprehend. It was also a help to engineers who were mathematicians, but who had forgotten some of the formulæ. What is now needed is a handbook which shall also express the mathematics in as clear a form as the results were expressed in Trautwine's book, and some progress has already been made in that direction.

The principles of Chemistry are as capable of cartographic representation as those of any other science. Mr. Sleeper of Jersey City appears to be doing good work in this direction.

In 1854, Dr. J. P. Cooke, our late President, prepared a table showing the relation of the properties of the elements to their atomic weights, in connection with a paper published by our society. Dr. Cooke then said: "To my mind chemistry will then become a perfect science when all substances have been classed in a series of homologues, and when we can make a table which shall contain not only every known substance, but also every possible one, and when by means of a few general formulæ we shall be able to express all the properties of matter, so that, when the series of the substance and its place in the series are given, we shall be able to calculate, — nay, predict its properties with absolute certainty."

Dr. Cooke's formula $(a + n\,d)$ expressed the same idea, — viz. the regular increase in the scale of atomic weights in each series, — whereas the law of the octaves of Newlands and Mendelcyeff only admits of seven elements in each period, and is inconsistent with this regular increase, which, as every new discovery tends to show, lies at the foundation of atomic chemistry.

All sciences owe a debt of gratitude to the naturalists for developing methods of classification that have been applied with such success. The advantages of public museums are too well recognized to require comment.

Of all sciences Geography was perhaps the first to be thoroughly expressed by the cartographic method. A picture suggests a map, and a map representing the prominent natural features suggests a map showing the political divisions of the land, the distribution of animal and vegetable life, etc. Geological Maps show the distribution of rocks, and Historical Maps the distribution of political supremacy at different ages.

I have already had the pleasure of calling the attention of the Academy to my own work in preparing a series of maps, designed to show the political divisions of Europe in every decade, or even at shorter intervals,

if necessary to make the representation continuous and complete in respect to time, and to present a complete panorama of history. In turning over the pages we see the growth and decline of nations and tribes. They move along as in a zoetrope or kinetoscope. In this Atlas, History is expressed in three dimensions. To find the state of Europe at a definite time, we only have to turn to the map of the date next following. To find the time that any nation or race first predominated in any spot, we only have to turn the leaves back until the color of that spot changes. The figures near the boundary line, when known, indicate the precise year in which the change occurred. No other atlas and no encyclopædia has ever attempted to supply complete information of such a character. Specialists have worked on such problems, each in his own sphere, but the results of their work lie buried in hundreds of periodicals and monographs, and have never before been combined and plotted. The objection has been raised that the use of charts takes away all the romance of history which is attached to the personal narrative, but it is by no means claimed that a knowledge of the geographical distribution of political supremacy comprises all that is useful in History. It is, however, the alphabet and foundation of Historical Science. Without it History is incomprehensible. If the reader keeps this Atlas before him and turns over its pages as he reads, the text will be clearer, the ideas will become associated with those already acquired, and the whole subject systematized and photographed on the mind. The Atlas serves as a nucleus for the crystallization of all associated ideas.

Statistical Science can only be properly handled in cartographic form.

The Historical Drama represents, in the four dimensions of space and time, the narrative and all the phases of history; the scenery and costumes, the manners and customs, the ideas and emotions, are presented simultaneously to the eye and the ear, so naturally as to produce a vivid and lasting impression. If artists and historians would combine their efforts to perfect the Drama, it could be made a powerful auxiliary to Historical Science.

The science and art of war require as much study and practice as any other science and art. But a soldier may not always be killing. He acquires practice in the elements of his profession in camp and garrison, but he can only apply them to a battle or a campaign by representing it in the field or upon a map. To aid in making this representation of war conform to the reality, all the information about the factors that influence a battle have been expressed in cartographic form by tabulating signs and abbreviations that would be meaningless in themselves, but

which serve to recall the contents of a volume. These tables are so arranged as to show the numerical value of the influences that affect a battle or a campaign, and, in connection with the scales and other apparatus, enable the umpire to make the representation of warfare as perfect as possible. Most of the methods that have been found so convenient in this exercise are equally applicable to any other art.

I think that some of the cartographic methods can be applied with great advantage to the study of languages, especially for a scientific man, who is obliged to read foreign languages from time to time without keeping in constant practice. A method that has been employed in reading French, Spanish, Italian, Latin, Greek, German, and Russian is as follows. One chart shows all the prefixes, affixes, etc. Another shows one thousand or more of the most common roots, arranged alphabetically. Ninety-nine words out of a hundred, more or less, can be found with these charts, and the labor of consulting the lexicon reduced in proportion. But that is not all. After you have used the chart a while, you recall what you are looking for as soon as you turn your head toward the chart, and often do not really look at it. Finally, it becomes photographed in your mind. After several years, if you take up the chart again, the associated impressions will come back to you. Special charts are made for special subjects, to be used in connection with the general chart.

In tabulating a language to speak it, a different method is employed. The chart of inflections is the same, but the words are arranged, not alphabetically, but according to meaning. When the object of language is merely to make your thoughts understood in a general way, without reference to elegance of expression, only a small vocabulary is required. If the words are arranged in the charts according to their meaning, the foreign words become associated in the mind with the ideas they express, and it is not necessary to think first in your native language and then translate alphabetically.

After applying these principles to one language of the Aryan family, it is very easy to apply it to another, and it is about as easy to learn to read ten languages by this method as one by the ordinary one.

For the commercial traveller this method may not be as expeditious as the more natural one, to accompany the word with the action, the action with the word, if the object be only to go to the door, turn the knob, look out of the window, etc.; but the scientific man has other needs.

The Fine Arts are more or less dependent for their production

upon the useful arts and the sciences. The same methods can be employed to investigate and communicate the principles on which they are founded.

Sculpture and Painting are addressed to the eye.

Sculpture is expressed in three dimensions of space. In contemplating a beautiful figure, we see and feel what we cannot express in sentences.

Painting is expressed in two dimensions, and through the medium of form and color impresses upon the mind volumes of thought and feeling.

Music is addressed to the ear; it depends upon a succession of sounds, and the music of the savage is only a melody that may be expressed on a scale by a single line or a succession of dots. On the other hand, the music of an orchestra is composed of hundreds of sounds of various qualities, which in the opera combine with the dramatic elements to excite the thoughts and emotions. The music of the ancients bears the same relation to the music of the future that the Arts and Sciences of the past bear to the Arts and Sciences of the future.

Poetry, too, is addressed to the ear. A simple ballad suggests a simple train of thought, or perhaps a gentle shade of feeling; but the poetry of Shakespeare suggests with each word a dozen images. In the early youth of nations, before the Arts and Sciences were fully developed, the energies of the intellect were mainly directed upon the language. The old Celtic bards were never allowed to speak except in blank verse. In the poetry of Homer and Shakespeare we find a vigor and an inspiration utterly wanting in later poetry. Abbott, in his Shakespearian Grammar, says: "We may perhaps claim some superiority in completeness and perspicuity for modern English, but if we were to appeal on this ground to the shade of Shakespeare in the words of Antonio in the Tempest, 'Do you not hear me speak?' we might fairly be crushed with the reply of Sebastian, 'I do, and surely it is a sleepy language.'"

Language may be regarded as the mother of all the sciences. She has brought them forth and nursed them, and they still depend upon her to introduce them to society. But it is time for them to cast off their swaddling clothes and learn to walk alone. In the future, language will not be overtaxed as it is at present, but will be none the less useful in its proper sphere. Thought must have other means of expression before all can co-operate to build up sciences to best advantage.

The earliest science was purely deductive. Philosophers evolved knowledge from the inner consciousness. The science of modern times has been mainly inductive, but the time has come when the results of induction must be put in shape to be combined in broader generaliza-

tions, which will enable the principles to be applied by deduction to cases that have not yet come within the scope of experience.

To Induction and Deduction we must now add Reduction in order to realize the full benefit of co-operation.

Societies like ours can exercise some influence in a quiet way to encourage co-operation. Our meetings also have more immediate advantages. The chief object in reading papers here is not to instruct the audience, but to lay before the society the lines of the author's work. Some suggestions may be brought out in the general discussion, but far more useful ones in personal conversation. Hence it is only at the social meetings that the full benefit can be expected.

The necessity for co-operation has long been recognized in the useful arts. In our factories we see men working together for a common purpose, in such a way that each may add the results of his labor to those of the others ; in an army co-operation is carried to the highest development. It is to be hoped that the future will witness large armies of scientists engaged not merely in collecting information and classifying it, but also in making systematic inductions and applying them to Arts and Sciences in general, and working in such a manner that each may add his results to the general stock.